IoT and Edge computing in health care: A bibliometric analysis

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***Abstract*— In healthcare, Internet-of-Things (IoT) technology has numerous applications, from smart wearables to implantable. With IoT in health care, physicians can monitor patient health and safety, as well as improve how they provide care. IoT health care market growth is driven by connected devices. Despite the rapid growth of wearable biomedical sensors in recent years, a pervasive IoT infrastructure remains a long way off. IoT, edge computing, fog computing, data analytics, and security are all required for developing end-to-end health data connectivity. In this paper, state-of-the-art health care solutions are reviewed using a bibliographic approach. Authors, organizations, countries are all quantitatively described in this paper. An analysis of keywords and co-citations is presented, showing the quantity and pattern of research in different fields. It is concluded by identifying future research challenges**

***Index Terms*— Edge computing, Fog computing, IoT, Health care, Bibliometrics.**

I. INTRODUCTION

There will always be new discoveries and a steady increase in scholarly journals and publications as humankind develops. The volume of scientific data will increase as well. Donthu et al., 2021 defined bibliometric analysis as "A popular and rigorous method for exploring and analysing large volumes of scientific data. It sheds light on the new areas in a specific field, while unpacking the evolutionary nuances of the field" [1]. They also describe how bibliometric analysis is conducted. Different indicators and how they are used. With the Web of Science collection, Wang et al., 2021 conducted a similar study on Edge computing for the Internet of Things. Several research areas were identified, including resource management, architecture, applications, and fusions of this field with artificial intelligence and 5G [2]. A lot of publications have been published since the study, most of them not specific to health care. Here, we present a bibliometric analysis of health care solutions based on IoT and edge computing.

This paper presents methodology adopted and research questions in section II. A comprehensive analysis is presented in section III. Finally, we discuss open issues, challenges, and suggest future directions in section IV.

II. METHODOLOGY

There are four distinct phases in this study: 1) Planning; 2) Data Collection; 3) Analysis; and 4) Reporting. Research questions and motivation for the study were formulated during the planning phase. For data collection, the dimensions database was searched using relevant key words, and the results were downloaded for analysis. Analyzing and visualizing data was performed with MS-Excel and VOS viewer. All the results are reported and maintained in GitHub

A. Planning

The purpose of this study is to achieve a comprehensive understanding of the state-of-the-art health care solutions using IoT and Edge computing. It is aimed at answering questions listed in Table1

Table 1 Research Questions

Research Question	Issues covered
RQ1: Annual scientific publications in IoT, edge computing and health care	▪ Number of studies published ▪ Year-on-year trend
RQ2: which journals are the most popular in in IoT, edge computing and health care	▪ Leading Journals in this field, total number of publications and citation index
RQ3: What are the most active countries in IoT, edge computing and health care research	▪ Top 3 countries based on citation analysis
RQ4: Who are the most active authors in the field of IoT, edge computing and health care research	▪ Who are the top 15 active authors according to publication count? ▪ What is the impact of each author in terms of h-

	index and the average citations per publication?
RQ5: what are the most influential literatures of IoT, edge computing and health care research	▪ When it comes to IoT, edge computing, and health care solutions, which research work has received the highest citations? – This identifies notable contributions recognized by peers
RQ6: what are the IoT, edge computing and health care hot spots?	▪ Research publications are analyzed using co-keyword analysis to establish relationships between studies.
RQ7: Key challenges associated with health care solutions based on IoT, edge computing.	▪ Review the survey papers and identify key challenges identified in the literature.

We analyzed the relevant research publications in the Dimensions database between 2018 and 2022 to answer these questions.

B. Data Collection

As part of our data collection process, we defined the inclusion and exclusion criteria and used appropriate search terms to collect relevant data required for a comprehensive bibliometric analysis. Table 2 and Table 3 summarize the approach we used to filter search results. We analyzed 328 articles relevant to Health care, IoT and edge computing extracted from Dimensions database.

Table 2 Search criteria

Particulars	Including	Excluding
Type of Database	Dimensions	Other databases
Period	From 2018 to 2022	Before 2018 and beyond Sep 2022
Publication Type	Articles	Book, Chapter, Monograph, Preprint, and proceedings
Search in	Title and abstract	Full data, DOI

Table 3 Search terms

Search term	# Records in dimensions
("Edge Computing" OR "Fog Computing")	11726
("Edge Computing" OR "Fog Computing") AND ("IoT" OR "IoMT" OR "Internet of things")	4779
("Edge Computing" OR "Fog Computing") AND ("IoT" OR "IoMT" OR "Internet of things") AND "Health"	328

III. ANALYSIS

If you are using Word, use either the Microsoft Equation Editor or the MathType add-on (http://www.mathtype.com) for equations in your paper (Insert | Object | Create New | Microsoft Equation or MathType Equation). ―Float over text‖ should not be selected.

A. Annual scientific publications

Research trends can be identified by observing variations in scientific publications over a specified period. It illustrates how intensely research is conducted in each field. Trend of IoT and edge computing solutions used in health care are illustrated in Figure 1. The number of publications continues to increase year after year indicating sufficient interest in research community.

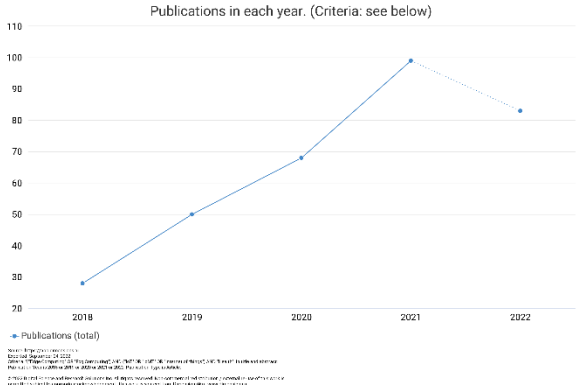

Figure 1 Publications year on year

B. Journals

Publishing in a highly regarded peer-reviewed journal is the goal for most research projects. Identifying the top journals in the area of research offers researchers a definitive list and guide to discover and select the most appropriate journals for their research. More than a fourth of all publications are published in the top five journals listed in Table 4. *Sensors* tops the list with 34 publications, while *Future generation computer systems* has the highest citation index mean among journals with more than two publications.

Table 4 Journals

Journal	Publications	Citations	Citations mean
Sensors	34	845	24.85
IEEE Access	26	960	36.92
IEEE Internet of Things Journal	17	717	42.18
Future Generation	7	1947	278.14

Computer Systems			
Procedia Computer Science	7	47	6.71

C. Countries

Using VOSviewer, we analyzed citations by country. The publications were spread across 54 countries, and a threshold of 5 publications was set which led to 20 countries. From the density visualization chart in Figure 2, India, China, and the United States are the top 3 countries contributing to the research in healthcare solutions using IoT and Edge computing.

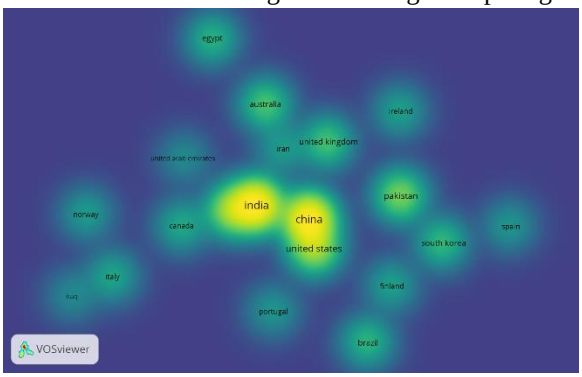

Figure 2 Countries

D. Authors

Here we present the top 10 most published researchers in healthcare, the internet of things, and edge computing. Table 5 shows their citations and citation mean. In this table, Sandeep Kumar Sood from the National Institute of Technology Kurukshetra has the most publications (8), followed by Joel José Puga Coelho Rodrigues from the Institute of Telecomunications, Portugal, and Sahil Sahil from Guru Nanak Dev University, India (5). Among authors with more than four articles, Pasi Liljeberg and Amir-Mohammad Rahmani have the highest citation mean (192.5) in terms of the influence of their research, suggesting that the authors publishing the most may not also be top-cited.

Table 5 Authors

Name	Publications	Citations	Citations mean
Sandeep Kumar Sood	8	318	39.75
Joel José Puga Coelho Rodrigues	5	96	19.2
Sahil Sahil	5	49	9.8
Munish Bhatia	4	35	8.75
Pasi Liljeberg	4	770	192.5
Amir-Mohammad Rahmani	4	770	192.5
Yaser I Jararweh	4	190	47.5
Thar Baker	4	398	99.5
Sukhpal Singh Gill	4	339	84.75
Mohammod Shamim Hossain	4	135	33.75

E. Influential literature

In Table 6, we show the top 10 highly cited articles in healthcare, IoT and edge computing between 2018 and 2022, as well as the Field Citation Ratio (FCR), which is a citation-based measure of an article's scientific impact.

Table 6 Influential Literature

Title	Times cited	FCR
Exploiting smart e-Health gateways at the edge of healthcare Internet-of-Things: A fog computing approach	664	251.76
Towards fog-driven IoT eHealth: Promises and challenges of IoT in medicine and healthcare	576	218.39
Survey on Multi-Access Edge Computing for Internet of Things Realization	379	141.79
Industry 4.0 and Health: Internet of Things, Big Data, and Cloud Computing for Healthcare 4.0	325	220.18
Internet of Things (IoT) for Next-Generation Smart Systems: A Review of Current Challenges, Future Trends and Prospects for Emerging 5G-IoT Scenarios	314	172.79
A new architecture of Internet of Things and big data ecosystem for secured smart healthcare monitoring and alerting system	310	117.54
Fog Assisted-IoT Enabled Patient Health Monitoring in Smart Homes	256	97.06
HealthFog: An ensemble deep learning based Smart Healthcare System for Automatic Diagnosis of Heart Diseases in integrated IoT and fog computing environments	245	164.73
A Survey on Internet of Things and Cloud Computing for Healthcare	215	66.34
A study on medical Internet of Things and Big Data in personalized healthcare system	150	53.04

F. Hot spots

Typically, keywords represent the main research area of an article, while cooccurrences and frequency of occurrences can indicate themes based on a particular subject. A thorough analysis of the research community's attention can help identify the domain's most significant challenges and sub-areas receiving the most attention. This section analyzes health care, IoT, and Edge computing research trends using keyword analysis and keyword co-occurrences in order to identify research gaps in the literature and possible future directions. In total, there were 9075 key words, of which 384 had at least 7 occurrences. The density graph was constructed using 60% of the most relevant words out of 384. Figure 3 highlights several key areas of interest, which include: Accuracy of predictions using convolutional neural networks, use of block chain, scheduling and response time for large traffic volumes, mobile edge computing, privacy of health data, and application in health care.

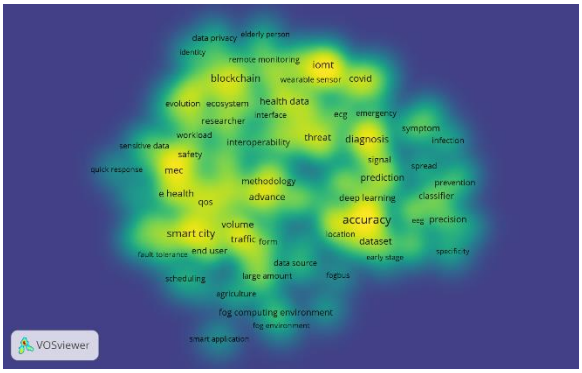

Figure 3 keywords

IV. OPEN ISSUES, CHALLENGES AND DIRECTIONS

In this section we review the most cited publications to understand the open issues, challenges and future directions of health care applications using IoT and edge computing.

(Farahani et al., 2018) present holistic architecture of IoT eHealth ecosystem and how it empowers data variety speed and latency. They also list challenges with respect to data management, scalability, regulations, Interoperability, security, and privacy [5].

(Porambage et al., 2018) describe how Multi access edge computing will inspire myriads of applications and services which require ultra-low latency and high quality of service [4].

(Jagadeeswari et al., 2018) highlight data security as a key requirement in health care and review existing solutions [12], (Aceto et al., 2020) echo the importance of security and propose architecture for secure smart health monitoring [6].

(Verma & Sood, 2018) describe how fog computing help solve real-time monitoring needs of health care. They propose an event triggering-based data transmission methodology to process patients' real-time data [9].

A comprehensive review of IoT privacy and security issues, including potential threats, attack types, and security setups, was presented by (Dang et al., 2019). IoT and cloud computing in healthcare face many challenges, including data security, system development processes, and business models, that are hindering their development [11].

(Rahmani et al., 2018) has proposed an architecture for fog assisted systems that involves strategically placing edge gateways. Edge gateways typically translate protocols between the internet and sensor networks. Embedded data mining, local storage, and processing can further enhance this [3] to address mobility, energy efficiency, scalability, and reliability concerns. There will be scalability issues if large data processing is centralized, since health care applications are sensitive to latency. (Tuli et al., 2020) propose a fog-based architecture to address issues such as power consumption, network bandwidth, latency, jitter, accuracy, and execution time. To meet the varying needs of users, architectures should be able to prioritize between prediction accuracy and quality of service [10].

(Shafique et al., 2020) emphasize the importance of differentiating services based on massive IoT (applications that require economical equipment, energy efficiency, scalability, and covering large areas) and critical IoT (availability, reliability and safety, and high quality of service, for example remote health care systems). The identification of the right parameter configuration, security/privacy, energy efficiency, and massive connectivity are other challenges highlighted [7].

In their discussion of the interrelationships between blockchain and fog computing, (Tariq et al., 2019) discuss blockchain as an enabler to address many security issues in IoT [13]. (Greco et al., 2020) examine AI's role in the context of IoMT, with a particular focus on leveraging fog and edge computing

for running AI algorithms [14]. A Bayesian neural network approach (EC-BNN), developed by (Manogaran et al., 2019), can be used to infer and identify various physical data collected from humans, inferring, and identifying them with high prediction accuracy. As a solution to the problem of multi-access physical monitoring systems, edge computing is a promising choice [15]. Using IoT and fog computing, (Santos et al., 2019) consider deep learning for fall detection. As their deep learning model, they propose a Convolutional Neural Network containing three convolutional layers, two maxpool layers, and three fully connected layers [16].

An optimal virtual machine selection method and a delay-aware task graph partition algorithm have been developed by (Chen et al. 2018) to minimize IoT device edge resource occupancy while ensuring QoS [17]. For smart healthcare systems, (Talaat 2022) use deep Reinforcement Learning (RL) algorithms in fog computing environments to achieve low latency and improve Quality of Service (QoS) metrics (allocation costs, response times, bandwidth efficiency, and energy consumption).

The studies indicate that the key challenges for health care applications include QoS, security, privacy, data management, reliability, scalability, interoperability, support for real-time and latency sensitivity, energy efficiency, massive connectivity, identifying the right system configuration. Some of the authors propose solutions to these challenges by proposing different architectures and using adjacent technologies such as 5G, multi-access edge computing, and AI. A new generation of digitally savvy consumers is seeking to reap the benefits of advanced software technologies. For now, it would be prudent to opt for services customized to their needs and in tune with the most updated features and technologies while the research continues to address key challenges discussed in this section

V. CONCLUSION

Considering COVID-19 patient safety has become a top priority, IoT-based medical apps have experienced unprecedented demand. However, IoT technology is not without its challenges when developing and incorporating it into healthcare. Research continues to solve these challenges. Developers are preparing to embark on their IoT and Edge computing journey in healthcare applications. However, early adopters must recognize these challenges and choose customized solutions that meet their needs. In health care applications involving IoT and edge computing, the authors would like to further research QoS, security, and privacy challenges.

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